R 326

Technical Report

AIR-FILTER SHIELDING FOR EMERGENCY SHELTERS

19 August 1964

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

AIR-FILTER SHIELDING FOR EMERGENCY SHELTERS

Y-F011-05-02-344

Type C

by

N. Oldson, C. A. Dittus and W. R. Nehlsen

ABSTRACT

Experiments were conducted to show which particle sizes of fallout falling from altitudes of 10,000 feet or more would be drawn into a typically protected shelter air intake. Results indicated that practically no particles over 60 microns in diameter would be captured. Some particles in the 30- to 60-micron-diameter size range were captured, and almost all particles below 30 microns in diameter were captured. Calculations made on two fallout-size distributions and three radioactivity levels indicate no significant hazard from material collected on the shelter air filters. Side-opening blast-closure devices, such as the AMF and OCD units, require additional protection to keep fallout from being captured by the high velocities at the inlet.

Shelters close to atomic blasts are likely to be subject to dangerous amounts of all sizes of particles coming from lower altitudes. These shelters must have all intakes closed during the danger period.

Copies available at OTS $0.50
Qualified requesters may obtain copies of this report from DDC.
The Laboratory invites comment on this report, particularly on the results obtained by those who have applied the information.

INTRODUCTION

Certain emergency shelters have extensive air-filtration systems designed to remove CBR contaminants from the shelter's incoming air. When the filters are located near the main shelter area, a potential radiation hazard may exist if the filters become heavily loaded with radioactive fallout particles. The objective of this task is to investigate the extent of this hazard and, if a sufficient hazard exists, to design a filter shield.

SHELTER FILTER SYSTEMS

Blast-protected shelters with CBR collective protection have ventilation filters capable of removing nearly 100 percent of all particulate material. The filter system contains an impingement prefilter capable of removing 5- to about 100-micron particles with high efficiency, and an absolute filter capable of removing nearly all particles of all sizes. The prefilter serves to minimize the dust load on the absolute filter. Although the prefilter is less effective on particles over about 50 microns, because inertia tends to carry them through, these larger particles are usually excluded by the intake and by sedimentation in the duct work.

FALLOUT CHARACTERISTICS

To accurately assess the hazard from accumulation of radioactive particles in the air and filter system, it is necessary to know the characteristics of the fallout that the system will be subjected to. Fallout occurs with surface and shallow sub-surface bursts whenever soil is mixed with the fireball. High-altitude bursts and deep-underground bursts do not cause any significant amount of local fallout. In most cases of surface or shallow sub-surface bursts, the contaminated soil will rise to an elevation of 10,000 to 100,000 feet, and the pattern of fallout can be predicted on the basis of average winds and falling times of variously sized particles. Definite percentages of the different particle sizes are usually used to simulate fallout from these high altitudes. A weight of material producing a fallout of about 10, 33, and 100 grams per square foot has usually been used by the Naval Radiological Defense Laboratory in fallout studies to simulate fallout corresponding to 300, 1000, and 3000 r per hour one-hour reference dose rates (detector three feet above infinite plane).

The size groups shown later are associated with these fallout levels, although variation in size groups will occur with different weapon-burst geometries and climatic conditions. Close-in fallout from partially underground bursts may not be separated into discrete size groups. In this case, large quantities of particles under 50 microns in diameter may be drawn into protected intakes. Consequently, the conclusions of this report, which depend on the falling-time separation of fallout into particle-size groups, are not valid for close-in shelters subjected to large quantities of fallout and ordinary dust of mixed sizes. Because of this and other dangers, such as fire and heat, close-in shelters normally keep all intakes closed or blowers shut off until the early blast effects have passed.

SUCTION-CAPTURE EXPERIMENTS

To obtain data on the actual amount of fallout that will be drawn into an air intake from a high altitude, several experiments were run. The test setup shown in Figure 1 was constructed for these experiments. The intake was designed as a model to represent a typical protected inlet that does not permit a direct downward or sidewise path into the air duct.

The air system was operated at 600 cfm through the 8-inch duct for an average velocity of about 1800 fpm. A removable filter was located in the duct system to retain all particles sucked into the intake. The filter was weighed before and after experiments to obtain data on how much simulant was sucked in.

The overhead rack shown in Figure 1 was about 7 feet above the inlet, and calculation showed this height to be adequate for typical particle sizes to reach approximate terminal velocities by the time they fell to the level of the intake. Approximate terminal velocities for several sizes are shown in Table I.

The first fallout simulant was a quantity of sand with the size distribution shown in Table II. This distribution is based on Naval Radiological Defense Laboratory (NRDL) test data from "Operation Redwing,"[1] and was used for this test because it contains some particles below 50 microns in diameter. The mixture was discharged from the spreader on the overhead rack. Although the terminal velocities would indicate that at least some of these smaller particles would be captured in the intake, the contrary proved true and none were drawn in. It is considered possible that the smaller particles were adhering to the larger ones and being carried past the inlet with them.

A mixture of 1- to 50-micron particles was then dropped from a 200-mesh strainer past the inlet, and it could be visually observed that practically 100 percent of this material falling near the inlet was captured. Since it appeared that the

50-micron size was the approximate dividing line between capture and dropping past the inlet, a new batch of material with sizes ranging from 30 to 60 microns was used for an additional test. With this material dropping past the inlet, it could be seen that particles falling within 6 inches of the edge of the conical cap were drawn into the inlet. Beyond this point, there was little or no capture.

During this test, 204 grams of material was dropped over an area of about 9 square feet. The capture area was found to cover about 5 square feet, so that 5/9(204), equal to 113 grams, fell through the capture area. When the filter was weighed, it showed that 42 grams had actually passed into the duct. Although refined testing might indicate more precisely what percentage of various sizes would be captured under ideal conditions, the results of these tests are considered to show that all particles over 60 microns will fall past a conical-capped inlet, approximately 40 percent in the 30- to 60-micron range will be sucked in, and nearly 100 percent of particles smaller than 30 microns passing through an inlet-velocity zone of about 200 fpm will be captured.

Significance of Inlet Particle Capture

The size distribution of fallout particles at a given location will be variable, but the amount of radioactivity involved is roughly proportional to the cumulative weight of each particle-size group. Table III shows a calculation of the amount of radioactivity that will be sucked in under several conditions, assuming that the percentage of particles captured at the inlet will be similar to the results of the suction-capture experiment. Fallout radioactivity levels of 300, 3000, and 10,000 r per hour are used as a basis for total weights of materials involved in the calculations in Table IV. Two particle-size distributions are used. One is that developed by NRDL and used by the U. S. Army Nuclear Defense Laboratory at Camp McCoy.[2] It is shown in Table IV. The other is the Redwing distribution from Table II. The Redwing distribution has a greater percentage of material in the smaller sizes. Since no particles over 60 microns in diameter were captured in the experimental tests, all particles larger than that are grouped as 60+ microns. A 10-hour period for the fallout to arrive is used in the analysis of the 300 r/hr reference dose rate.

Table IV shows that very little of the 150-300 micron NRDL simulant would be drawn in. Consequently, little or no radioactivity would accumulate on the filter, and no hazard would exist for the condition of a 600-cfm protected inlet. The Redwing distribution has a larger weight of material in the small-size ranges that will be captured, but Table III shows that the amount of radioactivity that will collect on the filter is small in all cases. The rate at 4 feet from collected fallout on the filter is smaller than that being received through the shelter walls. Nevertheless, some hazard would exist to anyone having to change the prefilter when it was newly contaminated. However, this filter would not necessarily require immediate changing, since for the 600-cfm unit only about 65 grams of fallout would collect on the filter, and this type of filter in a 20- by 20-inch size can hold several hundred grams. Unless the filter was very dirty before the fallout arrival, it could be left in place until the activity had decayed for a few days. However, it could safely be changed about one day after contamination if gloves were worn.

DISCUSSION

The experimental data showing that protected intakes will not capture any significant portion of fallout particles larger than about 60 microns is a reconfirmation of accepted design practice in shelter intakes. When the data is applied to particles from 150 - 300 microns, usually assumed as typical for fallout reference levels of 1000 to 3000 r per hour, there is practically no radioactivity collected on the filter and no danger to shelter inhabitants.

When fallout particles of the size that would come from a more distant detonation point reach an air intake, a larger percentage of them would be drawn in. Assuming that the smaller particles would not arrive until 10 hours after the detonation, the hazard to occupants is quite low.

Some increase of collected radioactivity will occur for larger sizes of ventilation systems. The hazard would increase from about 0.0125 r per hour indicated for a 600-cfm M9A1 system to about 0.025 r per hour at a 4-foot distance. This hazard is still relatively low and would decay to a fraction of this in 24 hours.

The importance of having a protected air intake should not be overlooked and is emphasized in NAVDOCKS P-81.[3] The AMF and Mosler blast closures have side openings with moderately high air-entrance velocities. The 36-inch AMF closures have an entrance velocity of about 1250 fpm at 10,000 cfm. When used as air intakes, these closures should be protected. Such protection exists in the entrance tunnel or can be provided by a blast-resistant shield above the valve, extending about a foot beyond the valve circumference.

CONCLUSIONS AND RECOMMENDATIONS

1. Fallout consisting of particles larger than about 60 microns will not be captured by protected air intakes.

2. A considerable percentage of fallout that occurs in the 30 - 60 micron range will be captured by a protected air intake, but the amount of radioactivity involved does not indicate a hazard to shelter occupants.

3. It is concluded that special shielding is not required for intake air filters.

4. All shelter air intakes should be protected against direct downward or sidewise entrance of fallout.

5. Precaution. The findings of this report should not be applied to close-in shelters receiving large amounts of fallout immediately after a blast.

REFERENCES

1. U. S. Naval Radiological Defense Laboratory. TR-314: Activity-size relationship of fallout particles from two shots, Operation Redwing, by H. K. Chan. San Francisco, California, 19 February 1959.

2. U. S. Army Nuclear Defense Laboratory. NDL-TR-32: Cold weather decontamination study — McCoy II, by J. C. Maloney, J. L. Meredith, J. Barnard, and C. C. Kilmer. Army Chemical Center, Maryland, July 1962.

3. U. S. Bureau of Yards and Docks. NAVDOCKS P-81: Personnel shelters and protective construction. Washington, D. C., September 1961.

4. Samuel Glasstone, ed. "The effects of nuclear weapons." Prepared by the U. S. Department of Defense. Published by the U. S. Atomic Energy Commission. Washington, D. C., U. S. Government Printing Office, April 1962.

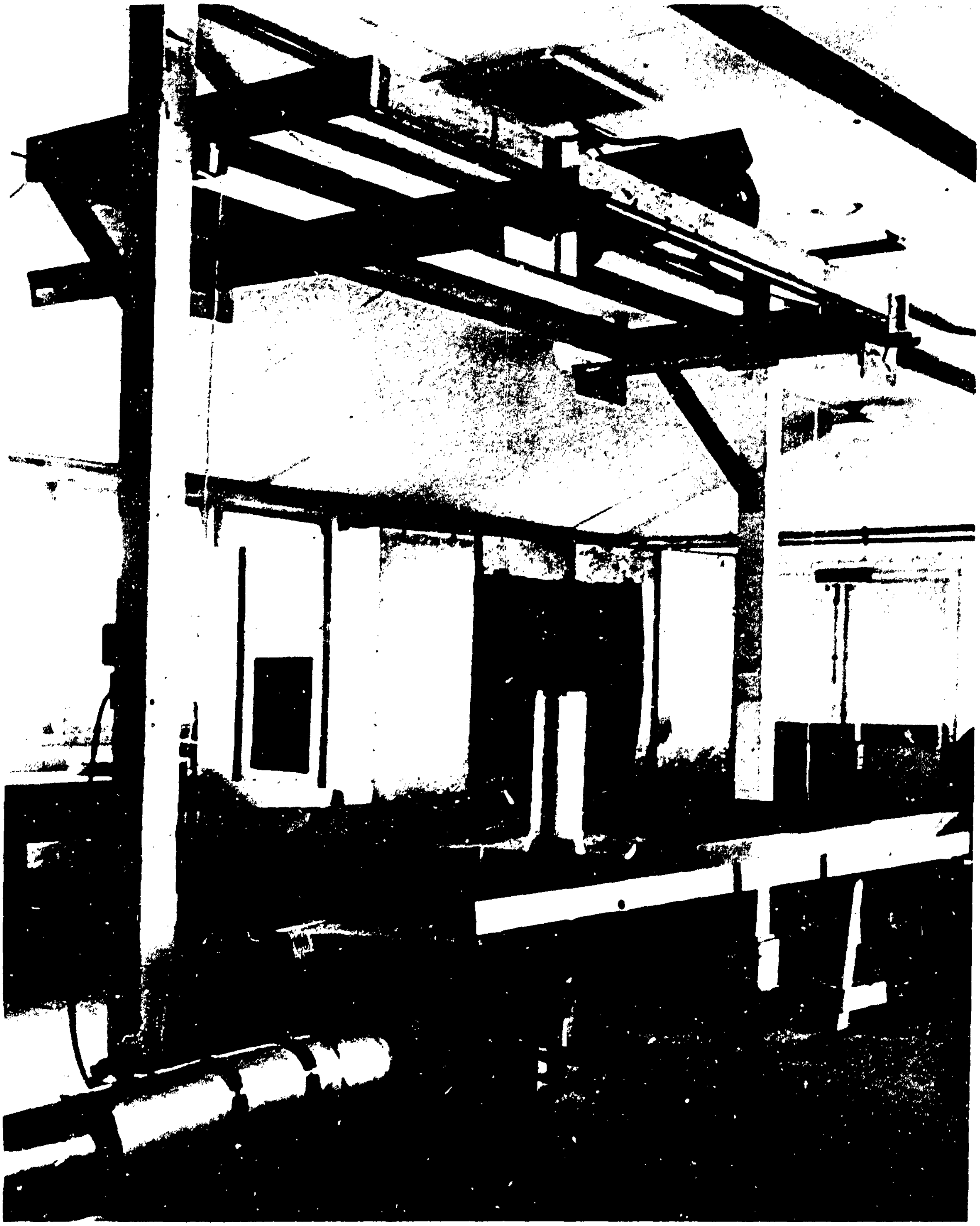

Figure 1. Test setup with sheet metal model intake for suction-capture experiments.

Table I. Terminal Falling Velocities for Various Fallout-Particle Sizes

Particle Diameter (microns)	Terminal Velocity[4] (fpm)
50	16
75	80
100	120
125	165
150	210
200	275
400	660

Table II. Particle Distribution Derived From Operation Redwing Data

Particle Diameter (microns)	Percent of Total by Weight
30 - 60	11
61 - 102	17
103 - 145	18
146 - 200	28
201 - 315	25
316 - 382	1

Table III. Filter Hazard Calculation

Particle Size (microns)	Percent by Weight	Curies to 5 ft^2	Particles Captured (%)	Curies Captured on Filter	Rate[1] 4 ft From Filter (r/hr)	Dose Rate From Outside, Protective Factor 1000 (r/hr)
300 r/hr (1 hr); 10 gm/ft^2; 0.16[2]/curies/ft^2 at 10 hr						
60+	89	0.71 (10 hr)	0	0	0	0
30-60	11	0.09 (10 hr)	37	0.033	0.0125	0.018
30-	0	0	100	0	0	0
3000 r/hr (1 hr); 100 gm/ft^2; 27 curies/ft^2 at 1 hr						
60+	99.8	134.73 (1 hr)	0	0	0	0
30-60	0.2	0.27 (1 hr)	37	0.10	0.04	3
30-	0	0	100	0	0	0
10,000 r/hr (1 hr); 330 gm/ft^2; 90 curies/ft^2 at 1 hr						
60+	99.8	449.1 (1 hr)	0	0	0	0
30-60	0.2	0.90 (1 hr)	37	0.33	0.125	10
30-	0	0	100	0	0	0

1/ Dose rate calculated from $D = 6CE/R^2$, where R = distance from source in feet; E = million electron volts; C = radioactivity in curies.

2/ Based on 0.009 curies/ft^2/r/hr at 1 hour.

Table IV. NRDL-NDL-McCOY Simulant Size Distribution

Particle Diameter (microns)	Percent of Total by Weight
44 - 88	0.18
88 - 105	0.10
105 - 149	1.21
149 - 297	56.10
297 - 350	30.38
350 +	12.00

DISTRIBUTION LIST

SNDL Code	No. of Activities	Total Copies	
	1	10	Chief, Bureau of Yards and Docks (Code 42)
23A	1	1	Naval Forces Commanders (Taiwan only)
39B	2	2	Construction Battalions
39D	5	5	Mobile Construction Battalions
39E	3	3	Amphibious Construction Battalions
39F	1	2	Construction Battalion Base Units
A2A	1	1	Chief of Naval Research - Only
A3	2	2	Chief of Naval Operation (OP-07, OP-04)
A5	5	5	Bureaus
B3	2	2	Colleges
E4	1	2	Laboratory ONR (Washington, D. C. only)
E5	1	1	Research Office ONR (Pasadena only)
E16	1	1	Training Device Center
F9	7	7	Station – CNO (Boston, Key West; San Juan; Long Beach; San Diego; Treasure Island; and Rodman, C. Z. only)
F17	6	6	Communication Station (San Juan; San Francisco; Pearl Harbor; Adak, Alaska; and Guam only)
F41	1	1	Security Station
F42	1	1	Radio Station (Oso and Cheltanham only)
F48	1	1	Security Group Activities (Winter Harbor only)
F61	2	2	Naval Support Activities (London and Naples only)
F77	1	1	Submarine Base (Groton, Conn. only)
F81	2	2	Amphibious Bases
H3	7	7	Hospital (Chelsea, St. Albans, Portsmouth, Va., Beaufort, Great Lakes; San Diego; and Camp Pendleton only)
H6	1	1	Medical Center
J1	2	2	Administration Command and Unit – BuPers (Great Lakes and San Diego only)
J3	1	1	U. S. Fleet Anti-Air Warfare Training Center (Virginia Beach only)
J19	1	1	Receiving Station (Brooklyn only)
J34	1	1	Station – BuPers (Washington, D. C. only)

DISTRIBUTION LIST (Cont'd)

SNDL Code	No. of Activities	Total Copies	
J46	1	1	Personnel Center
J48	1	1	Construction Training Unit
J60	1	1	School Academy
J65	1	1	School CEC Officers
J84	1	1	School Postgraduate
J90	1	1	School Supply Corps
J95	1	1	School War College
J99	1	1	Communication Training Center
L1	11	11	Shipyards
L7	4	4	Laboratory – BuShips (New London, Panama City; Carderock; and Annapolis only)
L26	5	5	Naval Facilities – BuShips (Antigua; Turks Island; Barbados; San Salvador; and Eleuthera only)
L42	2	2	Fleet Activities – BuShips
M27	4	4	Supply Center
M28	6	6	Supply Depot (except Guantanamo Bay; Subic Bay; and Yokosuka)
M61	2	2	Aviation Supply Office
N1	6	18	BuDocks Director, Overseas Division
N2	9	27	Public Works Offices
N5	3	9	Construction Battalion Center
N6	5	5	Construction Officer-in-Charge
N7	1	1	Construction Resident-Officer-in-Charge
N9	6	12	Public Works Center
N14	1	1	Housing Activity
R9	2	2	Recruit Depots
R10	2	2	Supply Installations (Albany and Barstow only)
R20	1	1	Marine Corps Schools (Quantico)
R64	3	3	Marine Corps Base
R66	1	1	Marine Corps Camp Detachment (Tengan only)
W1A1	6	6	Air Station
W1A2	35	35	Air Station
W1B	8	8	Air Station Auxiliary

SNDL Code	No. of Activities	Total Copies	
W1C	3	3	Air Facility (Phoenix; Naha; and Naples only)
W1E	6	6	Marine Corps Air Station (except Quantico)
W1H	9	9	Station - BuWeps (except Rota)
	1	1	Deputy Chief of Staff, Research and Development, Headquarters, U. S. Marine Corps, Washington, D. C.
	1	1	President, Marine Corps Equipment Board, Marine Corps School, Quantico, Va.
	1	1	Chief of Staff, U. S. Army, Chief of Research and Development, Department of the Army, Washington, D. C.
	1	1	Office of the Chief of Engineers, Assistant Chief of Engineering for Civil Works, Department of the Army, Washington, D. C.
	1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: Engineering Research and Development Division
	1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: ENGCW-OE
	1	1	Director, U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va., Attn: Information Resources Branch
	1	3	Headquarters, U. S. Air Force, Directorate of Civil Engineering, Washington, D. C., Attn: AFOCE-ES
	1	1	Commanding Officer, U. S. Naval Construction Battalion Center, Port Hueneme, Calif., Attn: Materiel Dept., Code 140
	1	1	Deputy Chief of Staff, Development, Director of Research and Development, Department of the Air Force, Washington, D. C.
	1	1	Director, National Bureau of Standards, Department of Commerce, Connecticut Avenue, Washington, D. C.
	1	2	Office of the Director, U. S. Coast and Geodetic Survey, Washington, D. C.
	1	20	Defense Documentation Center, Building 5, Cameron Station, Alexandria, Va.
	1	2	Director of Defense Research and Engineering, Department of Defense, Washington, D. C.
	1	2	Director, Bureau of Reclamation, Washington, D. C.
	1	1	Facilities Officer, Code 108, Office of Naval Research, Washington, D. C.
	1	1	Federal Aviation Agency, Office of Management Services, Administrative Services Division, Washington, D. C., Attn: Library Branch

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	2	Commander Nevol Beach Group Two, U. S. Naval Amphibious Base, Little Creek, Norfolk, Va.
1	1	Commander, Pacific Missile Range, Technical Documentation Section, P. O. Box 10, Point Mugu, Calif., Attn: Code 4332
1	2	U. S. Army Engineer Research and Development Laboratories, Attn: STINFO Branch, Fort Belvoir, Va.
1	1	Systems Engineering Group, Deputy for Systems Engineering, Directorate of Technical Publications and Specifications, Wright-Patterson AFB, Ohio
1	2	Library of Congress, Washington, D. C.
1	100	Director, Office of Technical Services, Department of Commerce, Washington, D. C.
1	1	Commander, Air Research & Development Command, Andrews Air Force Base, Washington 25, D. C., Attn: Library
1	1	Directorate of Research, Air Force Weapons Laboratory, Kirtland Air Force Base, N. M.
1	1	Mr. Walter Gunther, The Mitre Corporation, P. O. Box 208, Lexington, Mass.

U. S. Naval Civil Engineering Laboratory
Technical Report R-326
AIR-FILTER SHIELDING FOR EMERGENCY SHELTERS, by N. Oldson, C. A. Dittus and W. R. Nehlsen
13 p. illus 19 Aug 64 UNCLASSIFIED

Experiments were conducted to show what fallout particle sizes falling from altitudes of 10,000 feet or more would be drawn into a typically protected emergency-shelter air intake. Results generally indicated that no filter shielding problems will occur. Shelters close to a blast, receiving low-level fallout, must rely on closing the intakes during critical periods.

Key Words: air-filter shielding; emergency-shelter air intakes; fallout protection

1. Emergency shelters — Air intake
I. Oldson, N.
II. Dittus, C. A.
III. Nehlsen, W. R.
IV. Y-F011-05-02-344

U. S. Naval Civil Engineering Laboratory
Technical Report R-326
AIR-FILTER SHIELDING FOR EMERGENCY SHELTERS, by N. Oldson, C. A. Dittus and W. R. Nehlsen
13 p. illus 19 Aug 64 UNCLASSIFIED

Experiments were conducted to show what fallout particle sizes falling from altitudes of 10,000 feet or more would be drawn into a typically protected emergency-shelter air intake. Results generally indicated that no filter shielding problems will occur. Shelters close to a blast, receiving low-level fallout, must rely on closing the intakes during critical periods.

Key Words: air-filter shielding; emergency-shelter air intakes; fallout protection

1. Emergency shelters — Air intake
I. Oldson, N.
II. Dittus, C. A.
III. Nehlsen, W. R.
IV. Y-F011-05-02-344

U. S. Naval Civil Engineering Laboratory
Technical Report R-326
AIR-FILTER SHIELDING FOR EMERGENCY SHELTERS, by N. Oldson, C. A. Dittus and W. R. Nehlsen
13 p. illus 19 Aug 64 UNCLASSIFIED

Experiments were conducted to show what fallout particle sizes falling from altitudes of 10,000 feet or more would be drawn into a typically protected emergency-shelter air intake. Results generally indicated that no filter shielding problems will occur. Shelters close to a blast, receiving low-level fallout, must rely on closing the intakes during critical periods.

Key Words: air-filter shielding; emergency-shelter air intakes; fallout protection

1. Emergency shelters — Air intake
I. Oldson, N.
II. Dittus, C. A.
III. Nehlsen, W. R.
IV. Y-F011-05-02-344

U. S. Naval Civil Engineering Laboratory
Technical Report R-326
AIR-FILTER SHIELDING FOR EMERGENCY SHELTERS, by N. Oldson, C. A. Dittus and W. R. Nehlsen
13 p. illus 19 Aug 64 UNCLASSIFIED

Experiments were conducted to show what fallout particle sizes falling from altitudes of 10,000 feet or more would be drawn into a typically protected emergency-shelter air intake. Results generally indicated that no filter shielding problems will occur. Shelters close to a blast, receiving low-level fallout, must rely on closing the intakes during critical periods.

Key Words: air-filter shielding; emergency-shelter air intakes; fallout protection

1. Emergency shelters — Air intake
I. Oldson, N.
II. Dittus, C. A.
III. Nehlsen, W. R.
IV. Y-F011-05-02-344